A GEORGIA WATERSHED ATLAS DIRECTORY

Olin M. Ivey[1], E. Lynn Usery[2] and W. Wayne Boone[3]

AUTHORS: [1]Executive Director, Georgia Environmental Organization, Inc. (GEO), 3185 Center Street, SE, Smyrna, Georgia 30080-7039, oivey@geoeco.org; [2]Department of Geography, University of Georgia, Athens, Georgia 30602-2502, usery@arches.uga.edu; and [3]Alabama Power Company, 600 North 18th Street, P.O. Box 2541, Birmingham, Alabama 35291, www boone@southernco.com.
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Abstract. In an effort to provide citizens in the Georgia region with information about watershed management and water quality, the Georgia Environmental Organization (GEO), the University of Georgia, and Southern Geographic Information Services, a corporate business unit of the Southern Company, have developed a geographic information system (GIS) database for a Georgia Watershed Atlas. The Atlas includes 14 major watersheds divided into 179 Ecobasins. In addition to base category data of boundaries, roads, lakes, and rivers, the Atlas database includes wetlands, federal and state superfund sites (CERCLA and HSRA), waste water discharge sites (NPDES), gauging stations, surface mines, solid waste sites, hazardous waste sites, national and state parks, airports, cities, urban and industrial intake and discharge sites, and water quality sampling sites. The database is being used to produce an Atlas/Directory with each Ecobasin represented on a 17x22-inch map and a corresponding information page. The database and Atlas production have been accomplished with GIS and digital mapping techniques described in this paper. The information pages are briefly described and the items included are listed

INTRODUCTION

As numbers of people and our demand for consumer goods and services continue to increase, water quality, availability, and quantity are critical concerns for many communities, states, nations, and the world as a whole. Georgia, while endowed with significant surface and groundwater supplies (Figure 1), has occasionally required water controls and limited uses for lawns, cars, and other perceived non-essential activities. The problems have occurred only in limited areas of Georgia, such as the Atlanta metropolitan area, and result primarily from the uneven distribution of people, water needs, and water supplies. Georgia cities in areas north of the Fall Line—the line of contact between the Piedmont and Atlantic Coastal Plain geomorphic provinces—rely primarily on surface water because the underlying crystalline geologic structures supply only limited quantities of groundwater. South of the Fall Line in the loose sediments of the Coastal Plain, groundwater occurs in abundance, and cities can tap this resource for their needs.

Much of Georgia's population depends on surface water. Over one-half of Georgia's approximately seven million people live in the Atlanta metropolitan area, 100 miles north of the Fall Line. Out of concern for future water supplies and, even more so, the quality of water being degraded by pollution of various kinds, the Georgia Environmental Organization (GEO) developed the concept of providing a series of publications and educational/organizing workshops to involve the general citizenry in water and watershed protection. The term "ecobasin" was coined to emphasize that watershed protection involves concern for all the habitat from ridgeline to ridgeline, not merely for the streams themselves.

At the 1997 Georgia Water Resources Conference, GEO presented three papers [Ivey; McGrath; Walker] outlining the vision, philosophy, and procedure for developing forthcoming citizen-oriented pubiications for watershed planning, protection, and management. As a result of the alliances formed out of the 1997 conference, the Atlas/Directory—*RIO (River Inventory for Organizing): A Georgia Watershed Atlas Directory* nears completion. All 179 maps are on display at this 1999 GWR Conference (along with some sample accompanying information pages) so that conference participants can provide additional information, suggest changes, and make corrections.

The Atlas/Directory consists of 14 major watersheds, each divided into ecobasins. Each ecobasin consists of a portion of a major stream and the tributaries that feed it. This concept enables

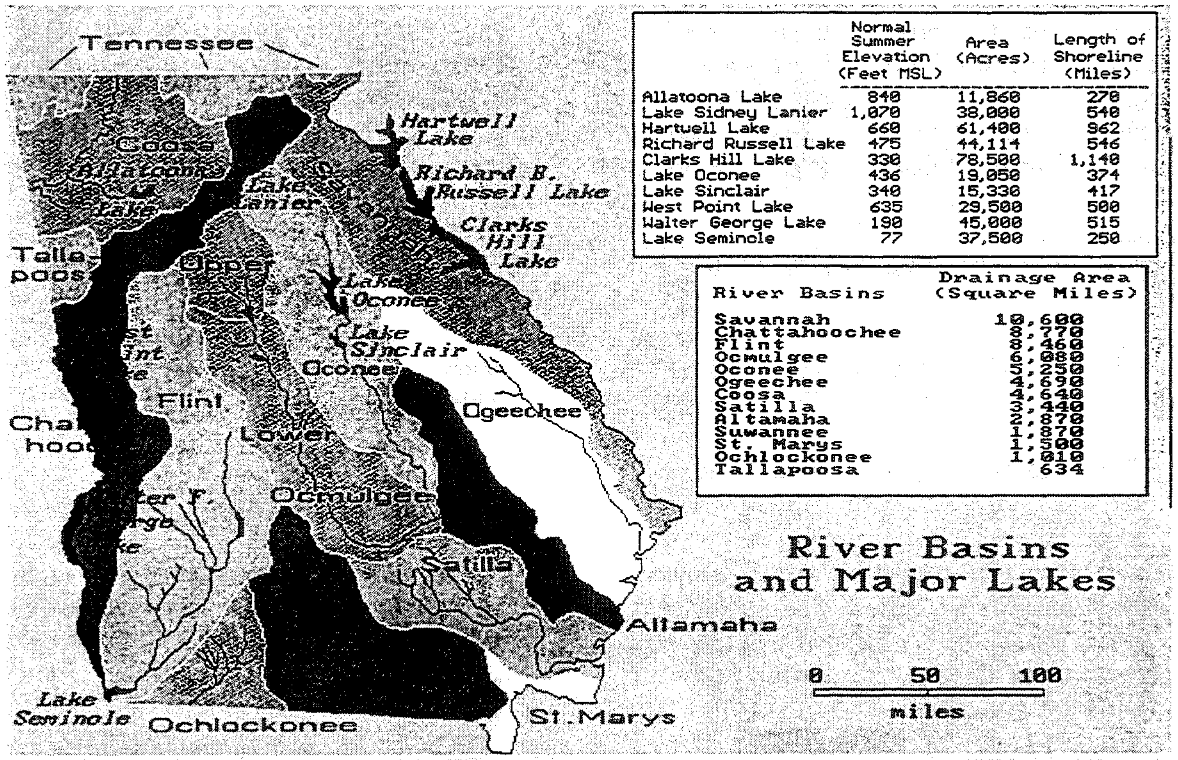

Figure 1. Georgia's watersheds and lakes (Source: Hodler, *et al.*, 1996).

citizens to envision their location within a watershed framework and to learn to speak in watershed terms. It provides an approach for mapping Georgia's surface-water supplies and the threats to them and their viability through construction of a Georgia Watershed Atlas. With funding and equipment support from Southern Geographic Information Services (Southern GIS) of Southern Company, GEO asked the University of Georgia's (UGA) Department of Geography to help develop the Atlas using graduate interns in geographic information science. Following is a brief description of the development of the Georgia Watershed Atlas/Directory. The next section details the project constraints, hardware, software, selected referencing system, and data layers. Section three documents development of the Atlas data layers while section four discusses the design and production of the final Atlas maps. A concluding section discusses the potential of the Atlas and plans for refinement and generation of higher resolution data layers.

BASIS OF A GEORGIA WATERSHED ATLAS

The Atlas began with attempts to define the constraints on the project, software, hardware, needed data layers, sources of data, and the processing steps that would result in the desired product. The primary constraint was funding support. To facilitate efficient compilation of the database and simultaneously provide a learning experience for a group of students, Southern GIS agreed to fund the database compilation for GEO if students at the UGA under an internship program performed the work. Since UGA offers certificates in geographic information science with an internship in geographic information systems [GIS] work as a part of the requirements, Southern GIS agreed to fund 12 student interns in the summer of 1997. Unlike traditional internships in which students work in-house with a private firm or government agency, the students worked at UGA in a GIS lab with a Novell Netware server dedicated to the project. An IBM RS/6000 was used as a support machine to provide a unix capability. Southern GIS further supported the project by providing UGA with additional hardware, particularly memory and disk capacity for the database development and additional student interns to generate the final maps. As the originator of the project, GEO gave overall supervision and kept the overarching vision of the project and complexity of detail ever before the interns. It furnished the HP Design Printer 2500 (commonly referred to as a "plotter"). Continual proofing and editorial supervision of both concept and detail would also be given by GEO. The support structure was thus in place to proceed with database construction.

Software used on the project includes ERDAS Imagine, and ESRI's Arc/Info and ArcView. The Imagine software was used primarily to generate and refine raster data layers while Arc/Info was used for vector data. The final ecobasin maps were to be compiled in ArcView with PostScript files generated for the printing process.

Selecting the reference framework for a statewide atlas can be problematic because of the demand for relatively high accuracy and broad total coverage. Most of the datasets to be acquired were based on the North American Datum of 1927 (NAD 27), thus this datum was selected. Since Universal Transverse Mercator (UTM) coordinates provide an accuracy of 1 part in 2,500, this system was desirable. However, Georgia spans two UTM zones which would compromise the accuracy if exact UTM specifications were used with only one zone. To meet the same accuracy and retain only one zone, a Transverse Mercator Projection with a central meridian of 83 W and the additional parameters in Table 1 was selected. The selected projection and parameters correspond to UTM with a shifted central meridian for projection.

Base category data were needed to provide a reference framework and a basis for definition of the basins and ecobasins. Initially, U.S. Geological Survey (USGS) hydrologic unit maps were to be used in the definition of basins and ecobasins. With only the 1:250,000-scale hydrologic unit code (HUC) maps available, the 14 basins could be delineated, but higher resolution data were needed for ecobasin definition. Southern GIS offered a seamless mosaic of the USGS 1:24,000-scale Digital Raster Graphics (DRG's) for the state of Georgia. This eight Gb file is too large and has too fine a resolution to use effectively for ecobasin delineation within the constraints of the project. It was decided that the initial work would require creation of a 1:100,000-scale seamless DRG for Georgia, which would be used for ecobasin delineation. This mosaic of two Gb of data was created by the interns, but the file size was still of such magnitude that it was divided into northern and southern sections of approximately one Gb each. From the two mosaics, further subsets were created to provide a basis for ecobasin boundary digitizing.

Table 1. Projection and Coordinate System Parameters for the Georgia Watershed Atlas

Datum	NAD 27
Projection	Transverse Mercator
Central Meridian	-83 °
Scale Factor	0.9996
False Easting	500,000

From the subsets of the 1:100,000-scale DRG mosaics, the interns created 179 ecobasins based on the drainage patterns and contours (Figure 2). These ecobasins then became the building blocks for the Atlas with each ecobasin created separately in ArcView. Additional base category data are included in Table 2.

DATABASE DEVELOPMENT

The GIS database was developed by acquiring data from the sources indicated in Tables 1 and 2 and converting each data layer to the specified datum, projection, and coordinate system.. Except for the DRG's which were only used in Imagine as a base for digitizing, raster layers, such as land cover, were originally processed in Imagine, then converted to Tagged Image File Format (TIFF) to be included in ArcView which was used for the development of the final ecobasin maps. Vector layers were initially processed in Arc/Info as Arc coverages then converted to shapefiles in ArcView to support the map generation phase of the project.

River Basin boundaries were taken directly from the USGS 1:250,000-scale HUC maps displayed in an Imagine viewer on top of the DRG mosaics. Ecobasin boundaries were digitized on-screen in Imagine from the 1:00,000-scale mosaics of the DRG's. Guidelines for ecobasin boundaries were provided to the project by GEO in the form of paper copies of the USGS 1:100,000-scale topographic maps with ecobasin boundaries marked. The student interns digitized the boundaries from the guidelines and their own interpretation of the contours (to determine ridgelines) on the DRG's. The digitized boundaries were saved in Arc/Info format for use in ArcView with the other layers.

Several data layers provided unique problems. For example, the land cover data were classified from 1988-91 Landsat Thematic Mapper (TM) images by ERDAS and the Georgia Department of Natural Resources (GA-DNR). With a pixel size of 30 meters, the original land cover file comprised over 340 Mb of data. Attempts to convert this file into an ArcView layer proved impossible without aggregation of the pixels to a coarser resolution. This generalization to a

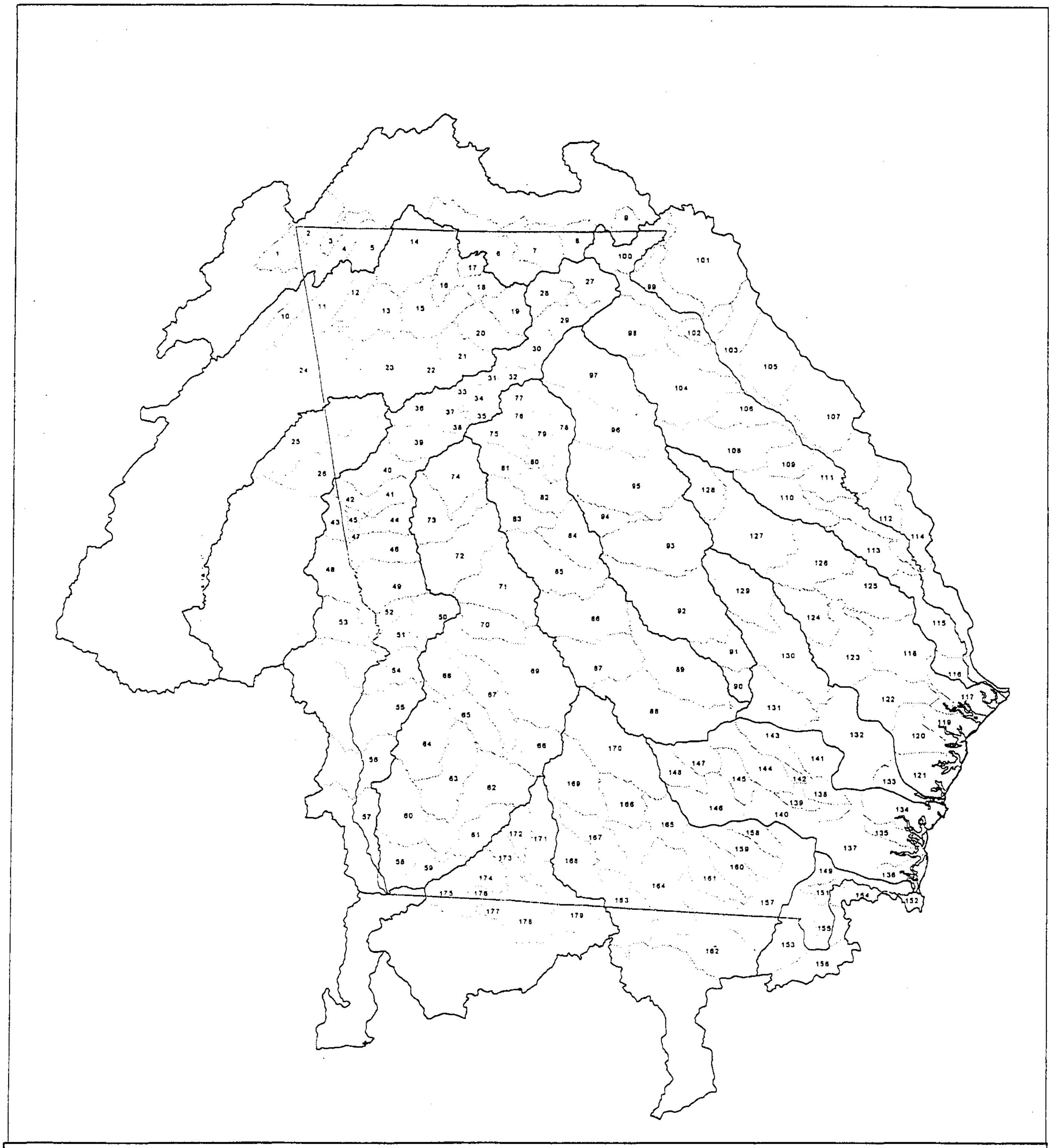

Figure 2. Basins and ecobasins included in the Georgia Watershed Atlas.

cell size of 100 x 100 m in Imagine allowed the layer to be included in ArcView and eventually converted to a vector coverage in shapefile format.

The roads layer was also problematic. Originally, the intention was to use the USGS 1:100,000-scale Digital Line Graph (DLG) data for Georgia. These data have been mosaicked into a single statewide coverage in Arc/Info export format by the Information Technology and Outreach Services (ITOS) office of UGA. However, the density of the road network at this

Table 2. Base Category Data for the Georgia Watershed Atlas.

Data type	Source of Data	Download site/media	Source scale/ resolution	Geographic extent*
State boundaries	USGS	www.usgs.gov	1:100,000	Georgia +
County boundaries	USGS	www.usgs.gov	1:100,000	Georgia +
River basins	USGS	www.usgs.gov	1:250,000	Georgia +
DRG	USGS	CD-ROM	1:100,000	Georgia +
DEM	USGS	www.usgs.gov	1:250,000	Georgia +
Roads	UGA	www.gis.ga.us	1:100,000	Georgia
Streams	USGS	www.usgs.gov	1:100,000	Georgia +
Lakes	USGS	www.usgs.gov	1:100,000	Georgia +
Cities	UGA	www.gis.ga.us	--	Georgia
Names	USGS	www.usgs.gov	--	Georgia +

*Georgia+ indicates Georgia plus portions of watersheds in bounding states (see Figure 2).

Table 3. Thematic Data for the Georgia Watershed Atlas.

Data type	Source of Data	Download site/media	Source scale/ resolution	Geographic extent*
Ecobasins	UGA	Created	1:100,000	Georgia +
Wetlands	GA-DNR	8 mm tape	30 m	Georgia
Land cover	GA-DNR	8 mm tape	30 m	Georgia
Forests	USGS	Csat.gatech.edu	1:100,000	Georgia
State parks	USGS	Csat.gatech.edu	1:100,000	Georgia
Airports	UGA	www.gis.ga.us	1:100,000	Georgia
Mining sites	EPA	EPA-Atlanta	--	Georgia +
Gaughing stations	USGS	fs1dgadrv.er.usgs.gov	--	Georgia +
Sampling sites	UGA	fs1dgadrv.er.usgs.gov	--	Georgia +
Solid waste	GA-DNR	GEO	--	Georgia
Hazardous sites	GA-DNR	GEO	--	Georgia
NPDES	GA-EPD	EPD-Atlanta	--	Georgia
CERCLA (Federal Superfund)	GA-EPD	EPD-Atlanta	--	Georgia
State Superfund sites	GA-EPD	EPD-Atlanta	--	Georgia
Intake sites (industrial/municipal)	GA-EPD	EPD-Atlanta	--	Georgia

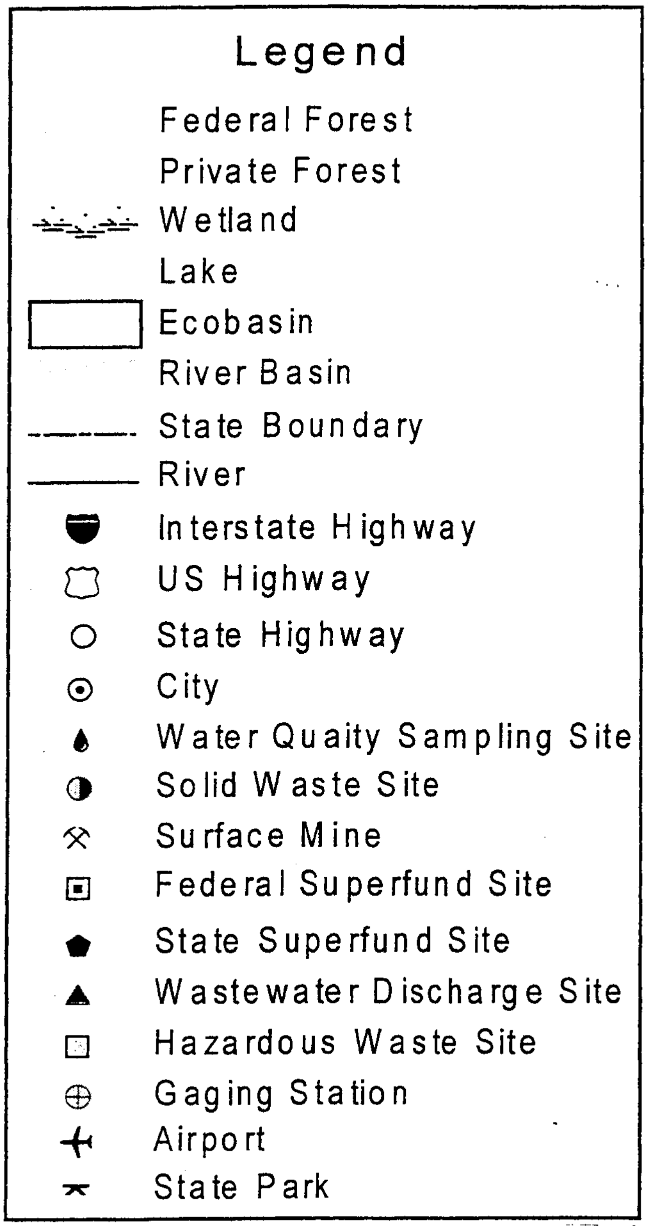

Figure 3. Symbols selected for use with the ecobasins of the Georgia Watershed Atlas.

resolution was too great to allow effective usage and obscured the other data layers on the final maps. A reduced set of roads consisting of interstate, U.S., and state highways was, therefore, acquired from the Georgia 100 GIS (ITOS, 1995) and used in the final database.

Additional problems occurred in several other layers. Generally, the problems related to data density and formatting. With significant perseverance the student interns were able to complete the database development.

ECOBASIN MAP DESIGN

Design of the final ecobasin maps required developing an effective layout and appropriate symbology to support the objective of conveying the hydrological data and potential sources of water-quality problems in an ecobasin. The design had to be effective to a non-professional audience since the target for the Atlas/Directory is the general public. In an attempt to adhere to common cartographic conventions and provide a standard look to 179 maps of varying sized areas with varying levels of detail, the project personnel settled on several general parameters. A range of scales is used to provide the maximum resolution based on the varying sizes of the ecobasins and the fixed 17x22 inch sheet size of the Atlas. Most maps were designed to fit scales in the range of 1:50,000 to 1:150,000 with scale increments of 25,000. For very large ecobasins, scales of 1:160,000 and smaller were used with increments of 5,000.

While many ecobasins in Georgia have the long axis in a north-south direction, some trend east-west and others have roughly equivalent dimensions in the cardinal directions. To maximize the level of detail presented, two basic layouts were selected for all maps. For a north-south basin, the selected layout placed the legend and inset location map in opposite corners, either northwest and southeast or northeast and southwest, and the scale and north arrow at the bottom adjusted to the shape of the basin (Figure 3). For east-west or equivalent dimension ecobasins, the selected layout places the inset map and legend at the bottom on opposite sides with the scale and north arrow roughly centered (Figures 4 and 5). River basin and ecobasin titles are placed at the top of the map in both layouts in the best position based on the ecobasin shape.

Symbology (see Figure 6) was selected to correspond to cartographic conventions whenever possible. With the varying sizes of the ecobasins and thus the varying scales, the selection of symbol sizes proved difficult. However, after experimentation with a variety of symbol types and sizes, the symbols shown in Figure 5 were selected. Road and city names appear in an Arial font. With their timely release in ArcView Version 3.1, road shield symbols were included for interstate, U.S., and state highways. Arrow indicators were included to show the inflow and outflow points of the major stream in each ecobasin. As a further refinement, the responses from the GWR Conference will be incorporated into the maps along with countylines, sub-continental-divide lines, and the

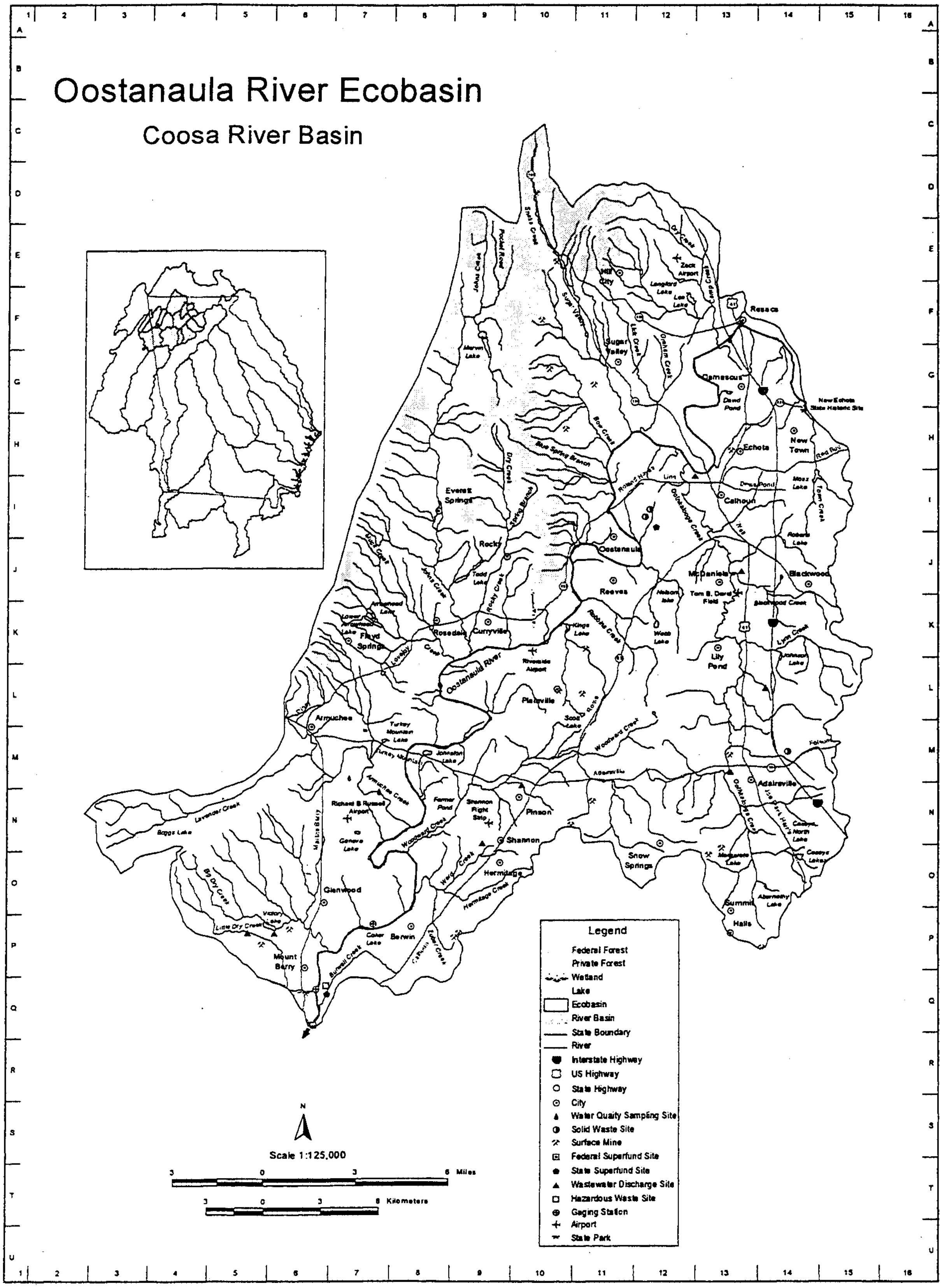

Figure 4. Example design, symbols, and layout for a north-south trending ecobasin. Note that this reduced image invalidates the representative fraction scale and degrades symbology. It is used to illustrate design, layout, and basic content.

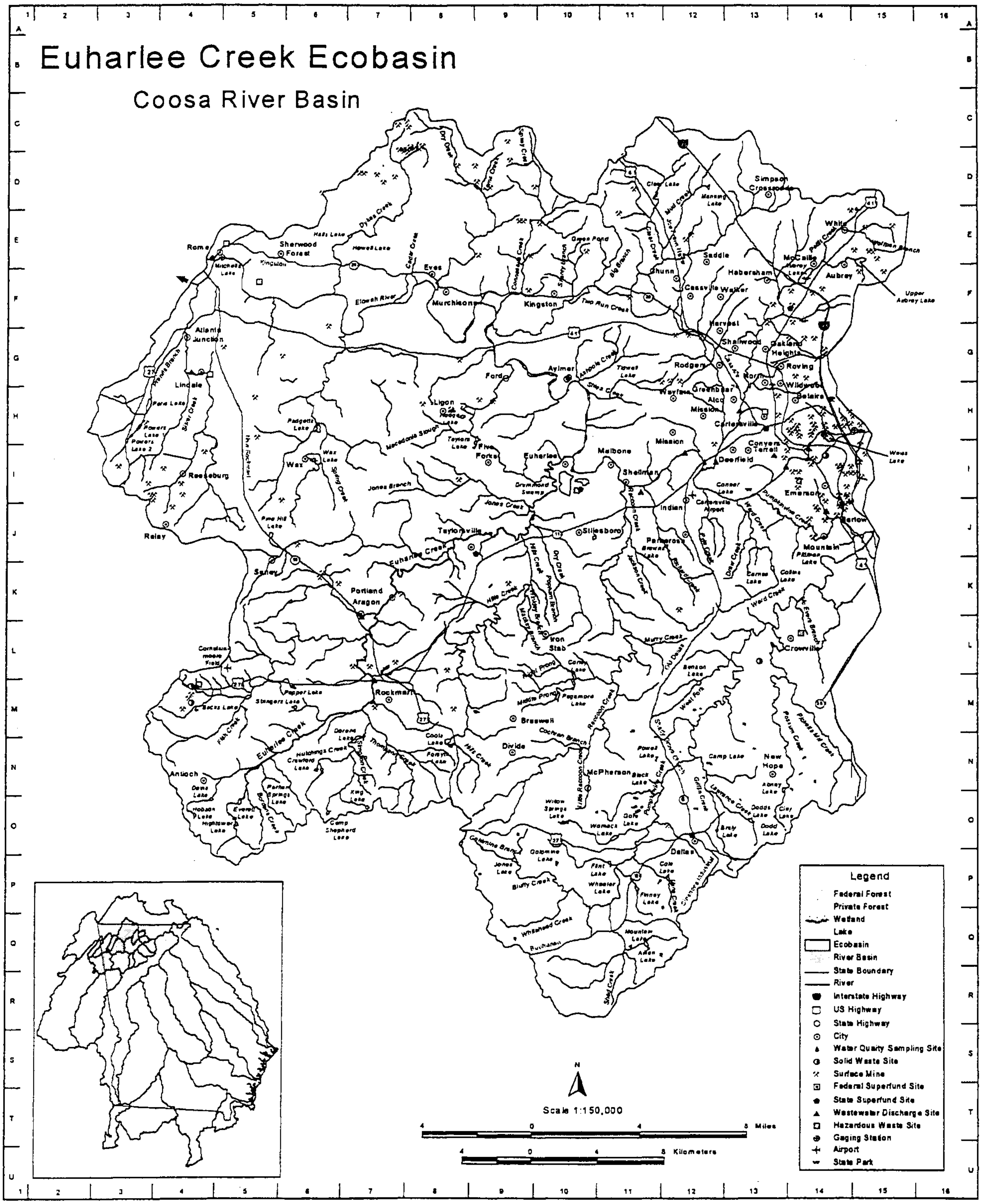

Figure 5. Example design, symbols, and layout for an equivalent direction ecobasin. Note that this reduced image invalidates the representative fraction scale and degrades symbology. It is used to illustrate design, layout, and basic content.

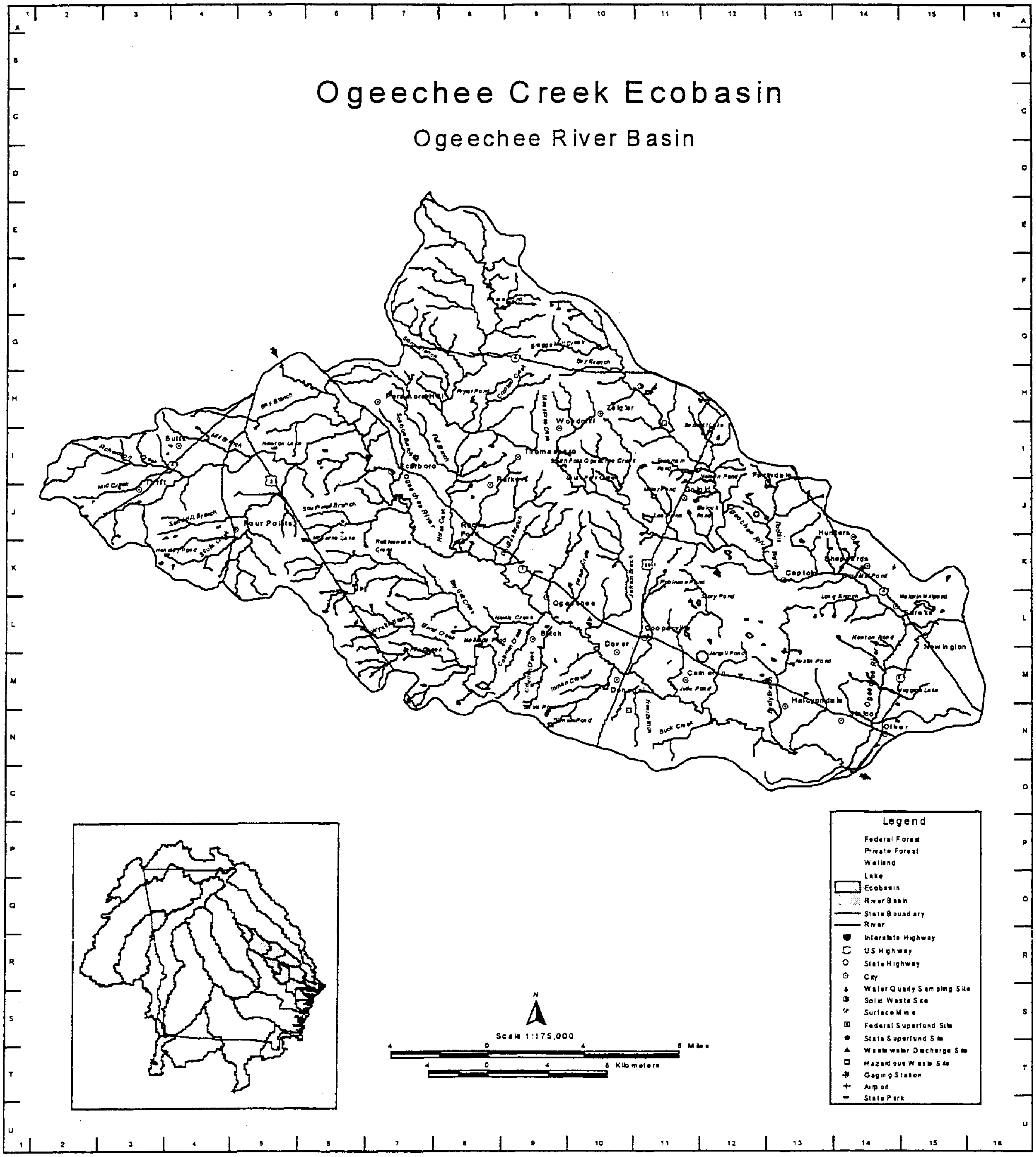

Figure 6. Example design, symbols and layout for an east-west trending ecobasin. Note that this reduced image invalidates the representative fraction scale and degrades symbology. It is used to illustrate design, layout, and basic content.

names and demarcating ticks indicating the adjoining ecobasins.

ACCOMPANYING INFORMATION PAGE

Accompanying each map will be an information page that provides the kind of directory information that will facilitate anyone working on water matters for that specific ecobasin. This information is vital in streamlining decision-making and making contact with appropriate stakeholders. Not only does it pinpoint the proper person to contact but it also relieves other decision-makers from having to consider matters not in their portfolio. Informational items include:

1. Ecobasin name and River basin name.
2. a location map of each county within the ecobasin
3. County Commissioners for each county in the ecobasin
4. County Soil and Water Conservation Chair for each county in the ecobasin
5. Water quality officials on local level—each county; major cities/towns
6. County personnel, Extension Service, USDA
7. County and/or regional personnel, Natural Resources Conservation Service
8. Regional planning groups and water officials
9. Hydrological schematic of the ecobasin
10. NPDES (permited wastewater discharge)sites (permitee, address, contact person, phone #, and point of discharge)
11. Water intake points
12. Monitoring sites
13. Solid Waste sites info
14. Federal Superfund site info
15. State Superfund site info
16. Hazardous Waste sites
17. Recreational areas within the ecobasin including State and National Parks
18. Non-profit environmental organizations in area
19. Water groups active in the area
20. Keep America Beautiful/Clean and Beautiful Person for each county (not all counties have one)
21. Adopt-a-Stream Programs

Many of these will be generated out of the GIS databases that created the maps. Others have been gathered through persistence in communication with various local, state, and national organizations as has been the case in the National and State Information Directory.

NATIONAL AND STATE INFORMATION DIRECTORY

Since decisions about local ecobasin concerns involve not only local personnel but also regional, state, and national personnel, GEO has collected the latest information on the following groups and agencies. This information will form a separate section within the various forms of published and digital-related products. Included are:

1. Statewide Elected (and some appointed) Officers
   - State
     - Governor
     - Lt. Governor
     - Secretary of State
     - Attorney-General
     - Commissioner of Labor
     - DOT Head
     - Public Service Commission Members
   - National
     - US Senators
     - US House of Representatives (include map of congressional districts)
2. Map of State House of Representative Districts
3. Map of State Senate Districts
4. Director, Associate Directors, Departmental Sections, and Water Sections, State EPD
5. Division Leaders and other water-related personnel of the Georgia DNR
6. US EPA Water Section, Region 4 and Top personnel, EPA Water Section, National
7. USGS personnel within Georgia
8. NOAA personnel related to Georgia
9. Officers and personnel of the Georgia Water and Pollution Control Association
10. Officers of the Georgia Groundwater Association
11. Officers of the Georgia Chapter, American Water Resources Association
12. Officers of the Georgia Soil and Water Conservation Commission
13. Officers of the Georgia Chapter, American Water Works Association
14. Officers of the Georgia Lake Management Society
15. Officers and Personnel of the Georgia Municipal Association
16. Key Personnel, Association of County Commissioners of Georgia
17. Officers of the Georgia Water Wise Council
18. Water Personnel, Corps of Engineers, Mobile District
19. Water Personnel, Corps of Engineers, Savannah District

20. Key Personnel, U S Fish and Wildlife
21. Key Personnel, U S Forest Service
22. Key Personnel, National Weather Service Southeast River Forecast Center
23. Statewide and county personnel, Extension Service
24. Statewide and regional personnel, Natural Resources Conservation Service
25. Personnel, Statewide Environmental Organizations
26. Water professors, UGA, GSU, and GIT (including faculty of the Institute of Ecology, UGA)
27. Key Personnel, Georgia Research Alliance
28. Key Private Consultants (both single shop and firms) in water
29. Map and accompanying information on personnel of the RDC's in Georgia
30. Map and accompanying information on personnel of Economic Development Districts in Georgia.

CONCLUSIONS AND FUTURE WORK

The database development for the Georgia Watershed Atlas is complete (except for the suggestions generated at the GWR Conference) and all 179 maps have been created in digital form. The maps are currently being edited and refined for final production. The accomplishment of this project leads to conclusions that the development of a large atlas can be accomplished at significantly reduced costs through the use of existing data sources and support from student interns. The project also illustrates the viability of private industry support of non-governmental organizations in cooperation with an academic institution to inform the public and help protect our environment. The learning outcomes for the students in this project have been significant. It has provided an opportunity for them to experience a real world problem and use their skills to make a contribution to its solution and provide a valuable service to the public in the form of the Georgia Watershed Atlas.

The immediate future work is to publish the Atlas/Directory as individual eco-basin maps for singular usage, in a CD ROM version, and in book form when funding is secured. Also, GEO and UGA are cooperating to gain funding support to create a World Wide Web site that will permit the entire Atlas to be immediately and directly available to the public. UGA work has already provided tools to support this access through operation of GIS software, specifically, Imagine, Arc/Info, and ArcView, through web browsers such as Netscape (Usery et. al, 1998). Additional work is planned to increase the resolution of the database. Initially, specific ecobasins will be upgraded to the 1:24,000-scale of detail but it is hoped that the entire Georgia Watershed Atlas can be updated in the near future. Communities sensing the need for a detailed resolution of their area (in the range, say, of 1:700') will provide the opportunity to create, eventually, such a data base for the entire state.

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